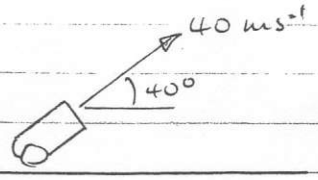
Questions on — Trajectories of projectiles — Momentum. **A level Physics**

A) Trajectories

1 A gun fires a shell at a muzzle speed of $40\ ms^{-1}$. If the barrel is at $40°$ to the horizontal, what are ...



(a) the maximum height of the shell's trajectory?

(b) the time of flight?

(c) the range?

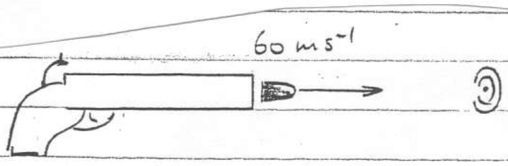
The gun is fired again at a new angle. A passing Physics student notices the shell is in the air for 3.0 sec.

(d) What is the gun barrel's angle to the horizontal now?

(e) How far does the shell go?

(f) What assumption(s) did you make?

2 A gun is held with the barrel exactly horizontal, and pointed at the centre of a target 20 m away. The gun fires a bullet at $60\ ms^{-1}$.



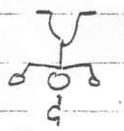
(a) How far <u>below</u> the centre of the target does the bullet hit?

(b) What is the <u>exact</u> velocity when the bullet hits the target?

B. <u>Momentum.</u>

3. — following Q.2 — if the mass of the gun is 800g and the mass of the bullet is 15g, what are the recoil velocity of the gun?

© TN 12.96.



HINTS ⟹ Hints ... Q.1 (d) what is the shell's <u>vertical</u> component of velocity?

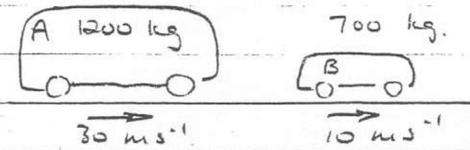
1(e) — and now the horizontal component?

2(a) — How long does the bullet take to reach the target?

— how far will it fall <u>vertically</u> in this time?

Projectiles + Momentum (2) A Physics

4 Large car A collides with B, and they both stick together.

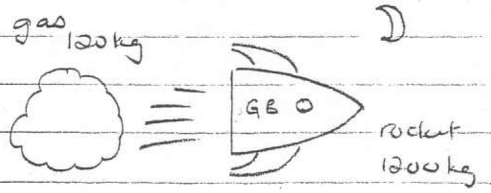


(a) What is the velocity of the combined cars after collision?

(b) Suppose car B is driving towards A when they collide. What velocity should car B have for both cars to be stationary after the collision?

(c) How does a seat belt help reduce injury in a car collision?

5. A rocket fires its motor for 2 minutes, and sends 120 kg of gas at a speed of 500 ms^{-1} relative to the rocket



(a) What is the forward force on the rocket?

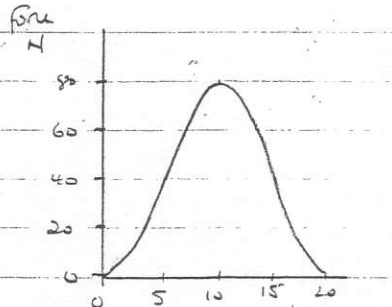
(b) What is the rocket's acceleration?

(c) What is the rocket's velocity at the end of the firing?

(d) Now.. use the Principle of Conservation of Momentum to calculate the rocket's velocity at the end of firing. Do answers to (c) and (d) agree?

(e) The mass of the rocket decreases during firing, why? How will this affect its acceleration + final velocity?

6 Tim Henman serves a tennis ball, mass 35g.
The graph shows how the force on the ball varies during the serve
What will be the ball's velocity just after the serve?



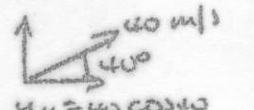
2N
96

Trajectories ANSWERS

Questions — Momentum {M = method mark} A level Physics

1 (a) vertical velocity (1) $v^2 = u^2 + 2as$ (1) $\Rightarrow s = v^2 - u^2/2a$ $u_V = 40\sin 40 = 25.7\,ms^{-1}$

$s = 0 - (40\sin 40)^2 / 2\times -10 = 33\,m$ (1) height. /4 ↑+ (1)



(b) vertical again (1) ... $v = u + at$ (1)

so t to max height $= v - u/a = 0 - 25.7/-10 = 2.57\,s$ ∴ flight = 5.14 s (1) $u_H = 40\cos 40$ (1) $= 30.6\,ms^{-1}$ /4

(c) range, $s = u_H t$ (1) $= 157.5$ (1) m /2

(d) for t = 3 s $u_V = v_V - at = 0 - (-10)1.5 = 15\,ms^{-1}$ (1) ; $u_V = u\sin\theta = 15 \Rightarrow \theta = 22°$ (1) /2

(e) new range $s = u_H t$ (1) $= 40\cos 22 \times 3 = 111\,m$ (1) /2 (f) air resistance = 0 (1) /1 $\boxed{15}$

2 (a) use $s = vt$ (1) so t to target, $t = s/v = 20/60 = 0.33\,s$ (1)

In 0.33 s bullet falls vertical distance $s = ut + \frac{1}{2}at^2$ (1) 0.55 m (1) /4

(b) $V_V = u_V + at$ (1) $= 3.3\,ms^{-1}$ (1), so $V_{true} = \sqrt{60^2 + 13.3^2} = 60.1\,ms^{-1}$ (1) $\theta = 3.2°$ (1) /4 $\boxed{8}$

3. $p_{gun + bullet}$ system = 0 p_{g+b} (before) = $p_g + p_b$ (after) (1)

$0 = m_g v_g + m_b v_b$ (1) $\Rightarrow v_g = -\frac{m_b}{m_g} v_b = -1.1\,ms^{-1}$ (1) backwards (1) →+ (1) $\boxed{5}$

(not 0)

4 (a) $(p_A + p_B)$ system = constant ... $p_A + p_B$ (before) = p_{A+B} (after) (1) Conservation of Momentum

$m_A u_A + m_B u_B = m_{A+B} v_{A+B}$ (1) u = before, v = after →+ (1)

$(1200\times 30) + (700\times 10) = (1200+700)\,V \rightarrow V = 22.6$ (1) ms^{-1} /4

(b) for cars to end up stationary $p_A + p_B = 0$ (1)

so $m_A u_A + m_B u_B = 0$ (1)

$(1200\times 30) = -700\,u_B \rightarrow u_B = -51.4\,ms^{-1}$ (1) (1) ← Fast, towards A! /4

(c) Since $f = (mv - mu)/t$ (1), a seat belt will reduce the force needed to change driver's p (1), and bring them to rest, by increasing the time (1) to do this. (equivalent to ↓ acceleration) /3 $\boxed{11}$

5 (a) over 2 min, $F_{on\,gas} = (mv - mu)/t$ (1) $= 120(-500 - 0)/120 = 500\,N$ (1) →+ (1) gas initially in rocket so u = 0

So force on rocket equal + opposite to force on gas = + 500 N (1) /4

(b) $a_{rocket} = F/m$ (1) $= 500/1200 = 0.42\,ms^{-2}$ /2 (c) $v = u + at$ (1) $= 50\,ms^{-1}$ (1) after 2 min /2

(d) Using conservation of momentum... (Rocket has 10× the mass, so 1/10 the velocity)

$p_{Rocket} + p_{gas} = $ constant (1)

assume $=0$ $m_{R+g} u_R = m_R v_R + m_g v_g$ (1) $0 = (1200\,V_R) + (120\times -500) \rightarrow V_R = +50\,ms^{-1}$ (1) forwards /3

(e) Rocket's mass ↓; gas ejected. $a = F/m$ — constant, ↓ (1) so a ↑ (1) /2 $\boxed{13}$

6. for ball $Ft = mv - mu$ (1) = area under F/t graph (1) $\approx \frac{1}{2} 80 \times 20 \times 10^{-3} = 0.8\,Ns$ (1)

so $m(v-u) = 0.8$ $v = 0.8/35\times 10^{-3} = 22.9\,ms^{-1}$ (1) (~55 mph — slow for Henman!)

TZM, Dec '96 $\boxed{4}$